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Acoustics — Measurement of sound insulation in buildings and of building elements using sound intensity —

Part 3: Laboratory measurements at low frequencies

Acoustique — Mesurage par intensité de l'isolation acoustique des immeubles et des éléments de construction —

Partie 3: Mesurages en laboratoire à de basses fréquences

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 15186 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15186-3 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

ISO 15186 consists of the following parts, under the general title *Acoustics — Measurement of sound insulation in buildings and of building elements using sound intensity*:

— *Part 1: Laboratory measurements*

— *Part 2: In-situ conditions*

— *Part 3: Laboratory measurements at low frequencies*

Annex A forms a normative part of this part of ISO 15186. Annex B is for information only.

Acoustics — Measurement of sound insulation in buildings and of building elements using sound intensity —

Part 3:
Laboratory measurements at low frequencies

1 Scope

1.1 General

This part of ISO 15186 specifies a sound intensity method to determine the sound reduction index and the element-normalized level difference of building elements at low frequencies. This method has significantly better reproducibility in a typical test facility than those of ISO 140-3, ISO 140-10 and ISO 15186-1. The results are more independent of the room dimensions of the laboratory and closer to values that would be measured between rooms of volume greater than 300 m^3. This part of ISO 15186 is applicable in the frequency range 50 Hz to 160 Hz but is mainly intended for the frequency range 50 Hz to 80 Hz.

NOTE For elements faced with thick, porous absorbers, the recommended frequency range is 50 Hz to 80 Hz.

The main differences between the methods of ISO 15186-1 and ISO 15186-3 are that in ISO 15186-3

a) the sound pressure level of the source room is measured close to the surface of the test specimen, and

b) the surface opposite the test specimen in the receiving room is highly absorbing and converts the room acoustically into a duct with several propagating cross-modes above the lowest cut-on frequency.

The results found by the method of ISO 15186-3 can be combined with those of ISO 140-3 and ISO 15186-1 to produce data in the frequency range 50 Hz to 5 000 Hz.

1.2 Precision

The reproducibility of this intensity method is, for all frequencies, estimated to be equal to or better than that found with the method of ISO 140-3 at 100 Hz.

Some comparisons of data obtained with the methods of this part of ISO 15186 and ISO 140-3 are given in annex B.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 15186. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 15186 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 140-1, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 1: Requirements for laboratory test facilities with suppressed flanking transmission*

ISO 140-3:1995, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 3: Laboratory measurements of airborne sound insulation of building elements*

ISO 140-10, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 10: Laboratory measurement of airborne sound insulation of small building elements*

ISO 9614-1:1993, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61043:1993, *Electroacoustics — Instruments for the measurement of sound intensity — Measurement with pairs of pressure sensing microphones*

3 Terms and definitions

For the purposes of this part of ISO 15186, the following terms and definitions apply.

3.1

average sound pressure level on a test surface

$L_{p\mathrm{S}}$

ten times the common logarithm of the ratio of the surface and the time average of the sound pressure squared to the square of the reference sound pressure

NOTE The surface average is taken over the entire test surface in the source room, including reflecting effects from the test specimen.

3.2

sound reduction index

R

ten times the common logarithm of the ratio of the sound power, W_1, incident on the test specimen to the sound power, W_2 transmitted through the specimen

$$R = 10 \lg \left(\frac{W_1}{W_2} \right) \text{ dB} \tag{1}$$

NOTE The expression “sound transmission loss” is also in use.

3.3

sound intensity

I

time-averaged rate of flow of sound energy per unit area oriented normal to the local particle velocity

NOTE This is a vectorial quantity which is equal to

$$\vec{I} = \frac{1}{T} \int_0^T [p(t) \cdot \vec{u}(t)] \, \mathrm{d}t \ \frac{\mathrm{W}}{\mathrm{m}^2} \tag{2}$$

where

$p(t)$ is the instantaneous sound pressure at a point, in pascals;

$\vec{u}(t)$ is the instantaneous particle velocity at the same point, in metres per second;

T is the averaging time, in seconds.

3.4
normal sound intensity
I_n
component of the sound intensity in the direction normal to a measurement surface defined by the unit normal vector $\vec{n}$

$$I_n = \vec{I} \cdot \vec{n} \tag{3}$$

where $\vec{n}$ is the unit normal vector directed out of the volume enclosed by the measurement surface

3.5
normal sound intensity level
L_{In}
ten times the common logarithm of the ratio of the unsigned value of the normal sound intensity to the reference intensity I_0

$$L_{In} = 10 \lg \left(\frac{I_n}{I_0} \right) \text{ dB} \tag{4}$$

where $I_0 = 10^{-12}$ W/m^2

3.6
surface-pressure intensity indicator
F_{pI}
difference between the sound pressure level, L_p, and the normal sound intensity level, L_{In}, on the measurement surface, both being time and surface averaged

$$F_{pI} = (L_p - L_{In}) \text{ dB} \tag{5}$$

NOTE This notation is according to ISO 9614-2. In ISO 9614-1 the notation F_2 is used.

3.7
residual-pressure intensity index
δ_{pI0}
difference between the indicated sound pressure level, L_p, and the indicated sound intensity level, L_I, when the intensity probe is placed and oriented in a sound field such that the sound intensity is zero

NOTE 1 It is expressed in decibels.

NOTE 2 Details for determining δ_{pI0} are given in IEC 61043:

$$\delta_{pI0} = (L_p - L_I) \text{ dB} \tag{6}$$

3.8
intensity sound reduction index
R_I
for one source room and one receiving room with an absorbing back wall, index defined by

$$R_I = L_{pS} - 9 - \left[L_{In} + 10 \lg \left(\frac{S_m}{S} \right) \right] \text{ dB} \tag{7}$$

where

L_{pS} is the average sound pressure level over the surface of the test specimen in the source room, in decibels;

L_{In} is the average normal sound intensity level over the measurement surface in the receiving room, in decibels;

S_m is the total area of the measurement surface(s), in square metres;

S is the area of the test specimen under test, in square metres.

NOTE Equation (7) is valid for a test specimen with a reflecting surface in the source room. It will also work satisfactorily for moderately absorbing surfaces (e.g. surfaces covered with 100 mm thick porous absorbers). For 100 mm to 200 mm thick absorbers, it is recommended to restrict the frequency range to 50 Hz to 80 Hz. For even thicker absorbers, the equation is no longer valid.

3.9
intensity element normalized level difference
$D_{I\mathrm{n,e}}$
difference given by

$$D_{I\mathrm{n,e}} = L_{p\mathrm{S}} - 9 - \left[L_{I\mathrm{n}} - 10\,\lg\left(\frac{A_0}{S_\mathrm{m}}\right) - 10\,\lg N\right] \qquad (8)$$

where

$L_{p\mathrm{S}}$ is the average sound pressure level over the surface of the test specimen in the source room, in decibels;

$L_{I\mathrm{n}}$ is the average normal sound intensity level over the measurement surface in the receiving room, in decibels;

A_0 $=$ 10 m^2;

S_m is the total area of the measurement surface(s), in square metres;

N is the number of small building element units installed within the measurement surface.

NOTE Equation (8) is valid for a test specimen with a reflecting surface in the source room. It will also work satisfactorily for moderately absorbing surfaces (e.g. surfaces covered with 100 mm thick porous absorbers). For 100 mm to 200 mm thick absorbers, it is recommended to restrict the frequency range to 50 Hz to 80 Hz. For even thicker absorbers, the equation is no longer valid.

3.10
measurement surface
surface totally enclosing the test specimen on the receiving side, scanned or sampled by the probe during the measurements

3.11
measurement distance
d
distance between the measurement surface and the specimen in a direction normal to the specimen

3.12
measurement sub-area
part of the measurement surface being measured with the intensity probe, using one continuous scan or discrete positions

4 Instrumentation

4.1 General

The intensity measuring instrumentation shall be capable of measuring intensity levels with reference to 10^{-12} W/m^2 in decibels in one-third-octave bands. The intensity shall be measured in real time when the scanning procedure is used. The instrument, including the probe, shall comply with IEC 61043:1993, class 1.

The residual-pressure intensity index δ_{pI0} of the microphone probe and analyser shall be higher than $F_{pI} + 10$ dB.

For most intensity probes, a 50 mm spacer is recommended.

The equipment for sound pressure level measurements shall meet the requirements of ISO 140-3.

4.2 Calibration

Verify compliance with IEC 61043 either at least once a year in a laboratory making calibrations in accordance with appropriate standards, or at least every 2 years if an intensity calibrator is used before each measurement series.

The following procedure shall be followed before each use of a sound intensity instrument to check that an instrument which has undergone type test and verification is still operating correctly.

a) Allow the instrument to warm up according to the manufacturer's instructions.

b) Set the instrument to the sound pressure mode and apply a class 0 or 1 or 0L or 1L sound pressure calibrator in accordance with IEC 60942 to the two microphones in turn or simultaneously, and adjust the instrument to the correct sound pressure indication in both channels.

c) Apply the residual intensity testing device to the two microphones and measure the pressure-residual intensity index and ensure that the instrument is within the requirements for its class in the range over which the residual intensity testing device operates. Phase compensation and any other procedures recommended by the manufacturer for performance enhancement may be applied. Phase compensation and pressure-residual intensity testing should preferably be done at a sound intensity and sound pressure level close to the levels of use.

d) If a sound intensity calibrator is available, use this to check the sound intensity indication.

5 Test arrangement

5.1 Rooms

Test rooms and test procedure shall be qualified as described in annex A.

Source and receiving rooms shall meet the room dimension requirements of ISO 140-1. The reverberation time of the source room shall meet the requirements of ISO 140-1.

The receiving room shall meet the requirements of the surface-pressure intensity indicator, F_{pI}, and the background noise; see 6.4.2 and 6.5 respectively. The wall in the receiving room opposite the test specimen shall be covered with an efficient sound- absorbing material. The other surfaces of the receiving room shall not be sound absorbing in the frequency range under consideration.

NOTE As sound absorber, use for example a 600 mm to 900 mm thick layer of fibrous material with a specific flow resistivity of approximately 10 kPa · s/m^2. The surface of the absorber can be covered by, for example, thin plastic film, less than 0,3 mm thick.

The filler wall in which windows, doors, etc. are mounted shall be dense (at least 300 kg/m^2). On the receiving room side the filler wall shall consist of another dense wall or a light covering. Thus, the filler wall forms a double construction. The mass-spring-mass resonance frequency should be less than 30 Hz.

5.2 Test specimen

The test specimen shall meet the requirements of ISO 140-3 or, for small building elements, ISO 140-10.

5.3 Mounting conditions

Mount the test specimen according to the requirements of ISO 140-3 or, for small building elements, according to ISO 140-10. If one side is sound absorbing, mount this side towards the source room. The distance between small building elements measured simultaneously shall be at least 2,4 m (i.e. twice the minimum distance given in ISO 140-10).

6 Test procedure

6.1 General

Measure the average sound pressure level over the surface of the test specimen in the source room and the average sound intensity level on a measurement surface in the receiving room. Provided that the surface-pressure intensity indicator is satisfactory, then calculate the intensity sound reduction index or, alternatively, the intensity element-normalized level difference.

6.2 Generation of sound field

Excite the source room by at least one corner loudspeaker or one continuously moving loudspeaker. If a corner loudspeaker is used, the surfaces forming the corner shall not be acoustically reactive; i.e. the constructions shall be solid and without loose layers near the surfaces. Any corner qualifying according to annex A may be used.

NOTE A corner loudspeaker can consist of a 30,48 cm (12 inch) unit in a closed triangular cabinet that fits into a corner and has an edge length of approximately 0,75 m. Smaller units and cabinets can also be used.

A moving loudspeaker shall meet the requirements of ISO 140-3 and travel along a straight line over a length of at least 2 m. The distance between the loudspeaker and the surfaces of the room shall be at least 0,7 m. The test object shall be outside the direct field. The line shall not be parallel to any surface of the room. Instead of a moving loudspeaker, at least five fixed positions along the line may be used. It is permissible to use multiple sound sources simultaneously, provided that they are of the same type and are driven at the same level by similar, but uncorrelated, signals.

The sound shall meet the requirements of ISO 140-3.

6.3 Measurement of the average sound pressure level over the surface of the test specimen in the source room

Measure the average sound pressure level over the surface of the test specimen in the source room by multiple fixed microphone positions evenly but asymmetrically distributed over the entire surface of the test specimen, including parts close to the edges and corners. The distance between the test specimen and microphone shall be less than 50 mm. Minimum numbers of microphone positions are given in Table 1.

Table 1 — Minimum number of fixed microphone positions on the test surface of the source room

Test specimen	Minimum number of microphone positions
Small building elements as defined in ISO 140-10	2 for each element mounted in the test wall
Other elements up to 3 m^2	6
Others	12

For each microphone position, the integration time shall be at least 30 s. Furthermore, if a moving loudspeaker is applied, the integration time shall cover a whole number of traverses.

If two or more fixed loudspeaker positions are used sequentially, the energy average of all loudspeaker and microphone positions shall be taken.

6.4 Measurement of the average sound intensity level on the receiving side

6.4.1 Measurement surface

On the receiving side, use a measurement surface totally enclosing the test specimen. If the test specimen is mounted in a niche, the measurement surface is normally the flat surface of the niche opening. If the test specimen is not mounted in a niche or if the depth of the niche is less than 0,1 m, use a box-shaped measurement surface. This will be the most common condition for small building elements.

NOTE For small building elements a hemispherical measurement surface could also be applicable.

Initially select a measurement distance, normally between 0,1 m and 0,3 m. Avoid measurement distances shorter than 0,1 m because of the near field of the vibrating element. In the near field the intensity tends to change sign very often. The sound field is also normally more uniform in the niche opening than inside the niche. When using box-shaped measurement surfaces, avoid measurement distances longer than 0,3 m.

6.4.2 Qualification of the measurement surface

Measure the time- and space-integrated normal sound intensity level $L_{I\text{n}}$. If possible, measure the time- and space-integrated sound pressure level L_p simultaneously. Then calculate the surface-pressure intensity indicator from equation (5):

$$F_{pI} = (L_p - L_{I\text{n}})\ \text{dB}$$

If the measured intensity is negative or if F_{pI} is not satisfactory (i.e. if $F_{pI} > 10$ dB for a sound-reflecting test specimen or if $F_{pI} > 6$ dB for a test specimen with a sound-absorbing surface in the receiving room), improve the measurement environment (only for two absorbing sides, because elements with one absorbing side are mounted with this side towards the source room; see 5.3). First try to increase the measurement distance by 5 cm to 10 cm. If this fails it may be necessary to decrease the flanking transmission or improve the absorption of the surface opposite the test specimen in the receiving room. For scanning, the sound field indicator requirement is valid for each scan and each loudspeaker position. However, it is only valid for the total measurement surface and not for individual measurement sub-areas. For discrete positions, it is valid for the surface average.

6.4.3 Scanning procedure

Always hold the probe normal to the measurement surface while scanning and direct it to measure the positive intensity outwards from the building element under test.

The measurement surface shall consist of one area or several sub-areas. The scanning time of each sub-area shall be proportional to the size of the area. Keep the scan speed constant. Select a speed between 0,1 m/s and 0,3 m/s. Interrupt the measurements when going from one sub-area to another. Avoid other stops.

Scan each area or sub-area using parallel lines, turning at each edge as shown in Figure 1. The required scanning line density depends on how irregular the sound radiation is. A large amount of irregularities such as leakages requires a higher line density. Normally select the line distance between scan lines to be equal to the measurement distance.

If the measurement surface is box-shaped as shown in Figure 2, give particular care to the areas close to the intersection between the box surface and the partition wall in which the test specimen is mounted. Attempts shall be made to ensure that all radiated sound intensity is measured by scanning the measurement surface properly. In particular, scan as close as possible to the partition wall.

